2015

The Royal Australian
and New Zealand
College of Radiologists®

Educational Modules for Appropriate Imaging Referrals

ADULT HEAD TRAUMA

This document is part of a set of ten education modules which are aimed at improving the appropriateness of referrals for medical imaging by educating health professionals about the place of imaging in patient care

PUBLICATION INFORMATION:
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More information is available on The Royal Australian and New Zealand College of Radiologists website:
URL: http://www.ranzcr.edu.au/quality-a-safety/program/key-projects/education-modules-for-appropriate-imaging-referrals

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The preferred citation for this document is:
Goergen S, Varma D, Tavender E, Rosenfeld JV, Cho S-M, Whiteman I, et al. Adult Head Trauma. Education Modules for Appropriate Imaging Referrals: Royal Australian and New Zealand College of Radiologists; 2015.

ACKNOWLEDGEMENTS:
The *Educational Modules for Appropriate Imaging Referrals* project is fully funded by the Australian Government Department of Health and Ageing under the Diagnostic Imaging Quality Projects Program.

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1. INTRODUCTION

WHAT IS HEAD TRAUMA?

HOW COMMON IS IT?
On average, 107 patients per 100,000 population are admitted to Australian hospitals with blunt head injuries each year.[1] Of these, approximately 20 per cent sustain moderate or severe head injuries and the other 80 per cent have milder injuries.[2] Mild head injury is a term that is sometimes used interchangeably with the terms “concussion” or “mild traumatic brain injury”. Males are twice as likely as females to experience head trauma and hospitalisation rates are highest for young adults (15 to 24 years) and seniors (75 years and older).[3]

WHAT CAUSES IT?
The leading causes of head trauma are motor vehicle accidents, falls, assaults and sports injuries.[3, 4] The majority of moderate to severe head injuries result from motor vehicle accidents with sporting injuries causing a higher proportion of mild injuries.[3]

WHAT ARE THE POTENTIAL ADVERSE CONSEQUENCES OF THIS CONDITION?

Head injuries are a leading cause of death and disability[5] and can result in long term or lifelong physical, cognitive, behavioural and emotional consequences that can affect a person's ability to perform daily activities and to resume relationships and employment.[6, 7] Approximately 39% of patients with severe head trauma will die from their injuries and 60% will have an unfavourable outcome on the Glasgow Outcome Scale.[7] Although the majority of patients will make a good physical recovery, more that 60% of people with moderate to severe head trauma report persistent cognitive changes (e.g. fatigue, attention deficits) and behavioural changes (e.g. excessive emotions, mood swings) up to 10 years post injury.[8]

Of those with mild head injury, less than 10% will have an intracranial injury (ICI) identified on CT and less than 1% will require neurosurgical intervention.[9] The majority will make a full recovery within a couple of weeks or months[10] however a proportion (5-25%) may experience persisting post-concussion symptoms including headache, dizziness, anxiety and lethargy that can lead to ongoing disability and adjustment problems.[2, 6, 8]

The lifetime costs of traumatic head injuries in the United States, including medical costs and lost productivity, have been estimated at $60 billion annually.[11]

	Mild	**Moderate**	**Severe**
GCS	14-15	9-13	3-8
Incidence (%)	80	10	10
Abnormal CT Scan (%)	5-15	30-50	60-90
Neurosurgical intervention (%) (excluding ICP monitoring)	<1 (<20 with abnormal CT need intervention)	5-30	30-50
Mortality (%)	<1	10-15	30-50
Good functional outcome (%)*	>90	20-90	<20
*Good functional outcome = independent activities of daily living (ADL) and to work or school at 6 months[12]			

TABLE 1 – SUMMARY OF CLOSED HEAD INJURY CLASSIFICATION AND OUTCOME[12]

HOW CAN IT BE DIAGNOSED?

Although several classifications of the severity of head injury exist, grading of head injury as mild, moderate or severe is commonly accepted, despite the criteria (in particular, the Glasgow Coma Score) that define each category being disputed. However, people with more severe injury in general have a lower score on the Glasgow Coma Scale (with a normal result being a GCS = 15).

Head injured patients should be assessed by a process of structured clinical assessment involving a combination of obtaining an accurate history of presenting illness, physical and neurologic examination, and serial clinical observations. Serial assessment is vital as a patient may rapidly deteriorate due to expanding haematomas or increasing swelling. The assessment should determine whether the patient has a high or low risk for significant brain injury.

History taking should include:

- Mechanism of injury (how the patient was injured) as certain mechanisms of injury are seen as 'red flags' indicating they are associated with an increased risk of intracranial injury (ICI). E.g. pedestrian struck by a motor vehicle.
- Symptoms associated with the injuries that are also associated with significant ICI; including duration of loss of consciousness, episodes of vomiting, focal neurological deficit.
- History of drug or alcohol use; including anticoagulant use, previous neurosurgery.

The physical examination should include an inspection for signs of:

- Skull fractures.
- Spinal injury.
- Vertebral and carotid artery dissection.

The neurological examination should include:

- Serial observation of vital signs.
- Glasgow Coma Scale (GCS) score.
- Cognitive functioning (anterograde, retrograde and post-traumatic amnesia).
- Pupillary reactions.
- Motor and balance testing.[4, 12, 13]

The Glasgow Coma Scale		
1. Best eye opening response	Spontaneous	**4**
	In response to speech	**3**
	In response to pain	**2**
	None	**1**
2. Best motor response	Obeys verbal commands	**6**
	Localises pain	**5**
	Flexion (withdrawal from pain)	**4**
	Flexion (abnormal)	**3**
	Extension (abnormal)	**2**
	No response	**1**
3. Best verbal response	Oriented in time, place, person	**5**
	Conversation is confused	**4**
	Speech is inappropriate	**3**
	Sounds are incomprehensible	**2**
	No response	**1**

TABLE 2 – THE GLASGOW COMA SCALE

IMAGING MODALITY OF CHOICE:

CT scanning is the imaging modality of choice in the patient with acute head injury who may require surgical intervention. It is fast, accurate, and readily available in most situations where there is an emergency medical treatment facility. CT scanning involves the use of ionising radiation. It is widely accepted that patients who do not have mild head injuries should receive a CT scan. For those with mild head injuries, a CT scan should only be indicated for those patients identified by structured clinical assessment as being at increased risk of intracranial injury.[12] When a CT scan is abnormal in a patient with mild head injury, the abnormalities usually do not require specific treatment. Injuries such as a non-depressed skull vault fracture, small haemorrhage in the brain (or "contusion") or bleeding outside of the brain (subarachnoid and small subdural haemorrhages) are the commonest findings in the minority of patients with mild head injury and an abnormal CT scan.

WHAT IS THE USUAL TREATMENT?

Severe/moderate head injury:

The management of head injuries focuses on the stabilisation of the patient and prevention of secondary brain injury. Resuscitation of the ABCDEs (Airway, Breathing, Circulation, Disability, Exposure) with adequate oxygenation and fluid resuscitation to prevent hypoxemia and hypotension are the priorities for patients with severe head injuries.[12] Hypoxia and hypotension are the greatest threat to functional outcome in brain injury. A CT scan of the brain should be obtained to identify any focal intracranial lesions requiring neurosurgical intervention.[12, 14] The neurosurgical service should be consulted about any patient with an acute neurological deterioration and if indicated the patient should be transferred to a neurosurgical facility.[12] Once the patient is transferred to the ICU, management should focus on maintaining haemostasis with stabilisation of the patient, prevention of intracranial hypertension, maintenance of an adequate and stable cerebral perfusion pressure, avoidance of systemic, secondary brain insults and optimisation of cerebral haemodynamics and oxygenation.[15]

Mild head injury:

Once it is determined that a mildly head injured patient is safe for discharge, all patients should be provided with verbal and written information including details of signs and symptoms of acute deterioration, when to seek urgent medical attention, reassurance that symptoms are likely to resolve, and advice on ways to assist recovery (e.g. activity limitations, information on typical post-concussion symptoms and when to seek routine medical follow up).[12]

What are the potential adverse consequences of performing imaging unnecessarily?

There are potential adverse consequences to the patient and the healthcare system of performing imaging unnecessarily. For the patient there is the unnecessary exposure to ionising radiation and the subsequent increased lifetime risk of cancer.[16] The risk posed by radiation is greater in younger adults due to the relatively increased sensitivity of younger tissues to the cancer-inducing effects of ionising radiation, the increased time for cancer to develop and the chance of cumulative lifetime exposure.[12, 16] The effective dose of ionising radiation associated with a single head CT scan in a 30 year old man is between 1 and 2 milliSieverts (1-2mSv) and this equates to an approximate increase in the lifetime risk of cancer of 1 in 10,000. To put this in perspective, the lifetime risk of cancer for all 30 year olds is about 3000 per 10,000 or about 1 in 3.

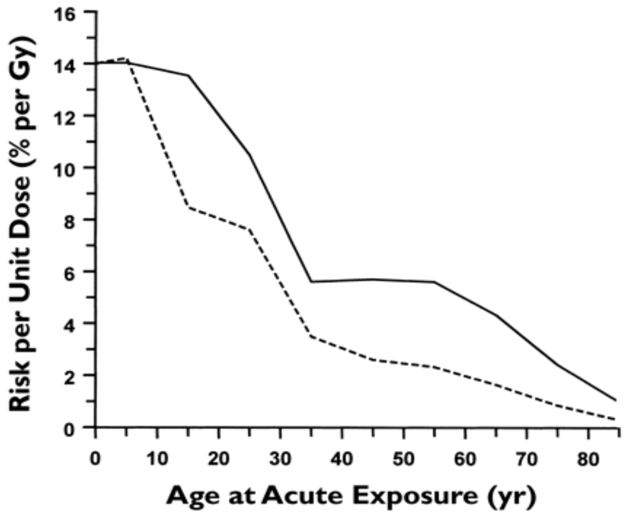

FIGURE 1: THE GRAPH SHOWS THE LIFETIME ATTRIBUTABLE CANCER MORTALITY RISKS PER UNIT DOSE AS A FUNCTION OF AGE AT A SINGLE ACUTE EXPOSURE AS ESTIMATED BY THE NATIONAL ACADEMY OF SCIENCES BEIR (BIOLOGICAL EFFECTS OF IONIZING RADIATION) COMMITTEE V REPORT (SOLID LINE) AND IN ICRP (INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION) REPORT 60 (DOTTED LINE).

Note the steep increase in lifetime risk with decreasing age at exposure.

The consequences for the healthcare system are the increased costs associated with the inappropriate use of resources and the subsequent increased workload for emergency, neurosurgery and radiology departments.

As mild head injury is common and the risk of cancer induction in younger people exposed to CT scanning is now reasonably quantifiable,[16-18] the risk associated with CT needs to be balanced against the risk of missing a clinically important injury if CT is not performed. Validated clinical decision rules can help to determine, more accurately, the likelihood of a clinically important intracranial injury being present and thus make a more informed decision about whether or not a patient should have a CT scan.

QUESTION 1:

What is the best estimate of the effective dose of radiation (in milliSieverts) delivered during a single non contrast CT scan of the brain performed on an adult?

1A. 0.1 mSv

1B. 1-2 mSv

1C. 10 mSv

1D. 15 mSv

1E. None of the above

CORRECT ANSWER:

The best estimate of the effective dose of radiation (in millisieverts) is

1B. 1-2 mSv

FEEDBACK: Remember that the effective dose of ionising radiation associated with a single head CT scan in a 30 year old man is between 1 and 2 milliSieverts (1-2mSv) and this equates to an approximate increase in the lifetime risk of cancer of 1 in 10,000. To put this in perspective, the lifetime risk of cancer for all 30 year olds is about 3000 per 10,000 or about 1 in 3.

QUESTION 2:

What is the best estimate of the ABSOLUTE additional lifetime risk of cancer attributable to one head CT scan performed in a 30 year old man?

2A. 1%

2B. 5%

2C. 0.5%

2D. 0.01%

2E. 0.2%

CORRECT ANSWER

The best estimate of the ABSOLUTE additional lifetime risk of cancer attributable to one head CT scan performed in a 30 year old man is:

2D. 0.01%

HOW CAN CLINICAL DECISION RULES HELP TO STANDARDISE PRE-TEST RISK EVALUATION OF PATIENTS WITH SUSPECTED INTRACRANIAL INJURY?

When evaluating patients with suspected intracranial injury, one of the key issues to be addressed is whether or not the patient should be investigated using imaging to confirm or refute the presence of an injury(ies) that would change the subsequent medical treatment or investigation of the patient. When attempting to make the decision about whether or not to use diagnostic imaging, it is important to focus on **features of the history and physical exam** that have been found to be associated with the presence of **clinically important intracranial injury**.

At first, it might seem simpler, quicker, and safer simply to perform an imaging test on everyone presenting with head trauma. When the pre-test probability of a condition is not very low, the costs and risks of diagnostic imaging are more than outweighed by the considerable benefits of earlier diagnosis of a potentially serious disorder. These benefits can include simpler, less invasive treatment or guidance for surgical or medical therapy that prevent severe disability or death.

However, there are a number of disadvantages to the practice of referral of patients for imaging without first considering what the pre-test probability of a condition is likely to be. They include:

- **Unnecessary exposure to ionising radiation**. This is particularly important in babies, children, and adolescents who are more sensitive to the carcinogenic effects of exposure to ionising radiation. CT scanning of the head is associated with 100-200 times the dose of radiation delivered by a plain chest radiograph (or x-ray).
- **Financial cost to the patient and health system of unnecessary testing**. These costs are both direct and indirect (the latter due to waiting time in emergency departments, prolonged length of stay in a hospital, time away from work and other responsibilities waiting for imaging to be performed, having it performed, and then waiting for the result).
- **Incidental findings on imaging frequently have no clinical significance for the patient but trigger further imaging follow up to exclude the very small possibility of something significant.** An example of this includes a small, asymptomatic, calcified lesion in the brain that may be revealed incidentally on a CT scan performed to rule out intracranial injury. The flow on costs to the patient and health system and the anxiety produced in some patients by follow up testing may not be considered when imaging is requested in a situation where pre-test probability of a condition is very low and imaging likely, therefore, to be unnecessary.
- **A test or process other than medical imaging may be a faster, less expensive way of ruling out clinically important pathology**. An example of this is observation of a patient with minor blunt head trauma either at home or in a hospital as an alternative to diagnostic imaging.

Continued increases in healthcare costs are a global problem. More than ever before, medical practitioners are being asked to be accountable for utilisation of finite health care resources and to add value and reduce waste in the care they deliver to patients. Reducing inappropriate use of diagnostic imaging in situations where it is highly unlikely to result in a net benefit to the patient is an important way to reduce waste and improve quality of care.

Clinical decision rules (CDRs) can help you to focus on the aspects of the history and examination that best discriminate between:

- **patients with very low risk of significant pathology** who are, therefore, unlikely to benefit from diagnostic imaging; and
- **patients who have higher risk** who need imaging to guide further specific treatment including in some cases in-hospital monitoring, medical therapy, or even surgery.

CDRs have been developed by gathering detailed clinical datasets from large numbers of patients with a particular condition, such as adults presenting to an emergency department following head trauma. They are comprised of a series of key examination findings (such as Glasgow Coma Score) and aspects of the history (such as injury mechanism) that have been found, when absent, to be associated with such a low risk (or pre-test probability) of clinically important injury that imaging is not required to further reduce this risk.

The emphasis of the current educational modules is on CDRs that involve risk assessment of patients with regard to their requirement for diagnostic imaging, but CDRs for other outcomes (such as prognosis) have also been developed.

The usefulness of **CDRs is that they help to reduce the subjectivity and inter-observer variation** involved in the clinical assessment of patients with specific conditions that sometimes, but not always, require imaging. Imaging is sometimes performed in these conditions to allow diagnosis of serious pathology. Using CDRs can help to increase your confidence about the safety of managing your patient without imaging when recognised clinical risk factors for serious pathology are entirely absent. Alternatively, they can help you identify patients who are at higher risk and require urgent imaging to confirm or exclude serious pathology so that treatment can be expedited.

Documentation in the medical record that you have used a high quality CDR to evaluate your patient and make management decisions based on this is not only good practice but increases the likelihood that another medical practitioner evaluating your patient would come to the same conclusions as you did about management.

Please see the Clinical Decision Rules Module for more information about:

- **what CDRs are;**
- **how they are developed; and**
- **what the characteristics of a high quality CDR are.**

Resources: Something that will become apparent as you work through these modules is the difficulty involved in trying to commit the elements of CDR to memory. It is a good idea to refer to an electronic or hard copy of the CDR each time you use it to ensure that you are applying it correctly. To support this, the following resources are provided:

- Printable PDFs of all of the CDRs including inclusion and exclusion criteria that need to be present or absent before the CDR can be used.
- "Pocket-sized" PDFs suitable for printing, lamination, and attachment to a lanyard.
- Links to the website MDCalc where you will find topic specific CDR "calculators" for some of the higher performing CDRs featured in these modules. These calculators allow you to enter responses to the questions of the CDR, without having to remember the individual elements of the CDR, and then "read" whether or not it is recommended that your patient have imaging based on the outcome of data entry into the CDR calculator. Go to the website now and try out the calculator for the Canadian CT Head Injury CDR:
    - *http://www.mdcalc.com/canadian-ct-head-injury-trauma-rule/*

For more information about specific imaging tests and procedures please see – *www.insideradiology.com.au*

WHAT ELSE DO YOU NEED TO THINK ABOUT WHEN YOU CONSIDER IMAGING A PATIENT WITH HEAD TRAUMA APART FROM PRE-TEST PROBABILITY?

1. **Test performance** (sensitivity, specificity, LR+ and LR-) in relation to the pathological process(es) you are trying to diagnose or exclude.

   A reminder about the definitions of the key diagnostic test performance metrics – these are derived from the 2 X 2 table representing disease state and the results of tests with binary outcomes (i.e. normal/abnormal, positive negative).

	Disease +	Disease -	Calculations
Positive test result	TP	FP	PPV = TP/(TP +FP)
Negative test result	FN	TN	NPV = TN/(TN + FN)
Calculations	Sens = TP/(TP + FN)	Spec = TN/(TN + FP)	Accuracy = (TP + TN) / (TP + TN + FP + FN)

Definitions:

- True positive (TP) = number of patients in whom the test result is positive when disease is present.
- False positive (FP) = number of patients in whom the test result is positive when disease is not present.
- False negative (FN) = number of patients in whom the test result is negative when disease is present.
- True negative (TN) = number of patients in whom the test result is negative when disease is not present.
- Sensitivity = proportion of patients WITH disease who have a positive test result.
- Specificity = proportion of patients WITHOUT disease who have a negative test result
- LR+ $= \frac{\text{proportion of patients WITH disease who have a positive test result (SENSITIVITY)}}{\text{proportion of patients WITHOUT disease who have a positive test result (1 – SPECIFICITY)}}$
- LR- $= \frac{\text{proportion of patients WITH disease who have a negative test result (1 – SENSITIVITY)}}{\text{proportion of patients WITHOUT disease who have a negative test result (SPECIFICITY)}}$

Note:

- High quality diagnostic tests have LR+ > 10 and LR- <0.1.
- A LR+ or LR- = 1 is associated with no change in the post-test probability of disease and therefore is not diagnostically useful.

2. **What is available locally,** especially in an emergency?
3. **Radiation dose**, of particular importance in young and pregnant patients.
4. **Financial and other costs to the patient and health system** of one diagnostic strategy compared with another.
5. **Renal function** in the case of imaging tests that involve the use of iodinated contrast media or gadolinium chelates (used for MRI).
6. **Patient preferences** – if two diagnostic tests perform equally well at confirming or excluding the presence of a particular condition, patients may have a preference for one over another for reasons of cost, convenience, risk, or real/perceived discomfort associated with a particular diagnostic test or strategy.

2. Clinical Decision Rules

How can Clinical Decision Rules help to determine pre-test risk of clinically important intracranial injury in patients with head trauma?

A number of CDRs exist that are applicable to patients with suspected intracranial injury. A high performing CDR has been defined by McGinn et al[19] as one with a sensitivity of >95% (with a lower limit of the 95% confidence interval for sensitivity of 95%) and a likelihood ratio for a negative result when using the CDR of 0.1 or less.

This means that a patient with a "negative result" using a high performing CDR has less than a 5% chance of having the clinically important outcome that the CDR is designed to exclude.

The following CDRs for patients with acute head trauma have been identified through a systematic search of the literature to be the best performing tools available for this patient group.

1. The Canadian CT Head Rule (CCHR).
2. The New Orleans Criteria (NOC).[20]
3. NEXUS II.[21, 22]

NOTE:

- **The Canadian CT Head Rule is the most widely validated and best performing of the three rules and is recommended for use in all patients with blunt head trauma who meet inclusion criteria and who do not have exclusion criteria that would preclude the use of this decision rule (see next page).**
- **Information about the other rules are included for educational purposes, because you may hear about them, and so you can see how the elements and performance of these other CDRs compare with the Canadian CT Head Rule.**

Information about the CDRs for adults with head trauma will address the following aspects of the CDR:

- A short summary of the nature of the CDR which includes:
  - an overview of the performance of the rule;
  - general inclusion and exclusion criteria;
  - precautions about routine clinical use of the CDR;
  - more detailed information about these aspects of the CDRs can be found in the evidence table (Appendix One) at the end of the module. It allows rapid comparison of the performance, inclusion and exclusion criteria for each CDR.
- Appendix One – Evidence Summary Table provides a summary of:
  - **The performance of the individual rules** based on the derivation study and/or the first validation if this was performed in conjunction with the derivation study.
  - **Inclusion and exclusion criteria for each CDR**. Note that the CDR or algorithm alone does not tell you the characteristics of patients to whom you can apply the CDR.
    - **Knowing the situations in which you CAN and CANNOT use a CDR** is just as important as knowing the elements of the CDR itself. Common exclusion criteria are things like patient age, whether the person is an inpatient (rather than an ambulatory outpatient), and use of anticoagulation.
  - **Validation studies** for the CDR including their performance and inclusion and exclusion criteria if these differ from the derivation study**.**
- The elements of the rule (generally a flowchart, series of questions, or list of examination or historical findings that need to be elicited).
- **Links** to the full text derivation studies for the individual CDRs.

Throughout this module, you will be presented with questions that will evaluate module content and also your ability to apply this to real clinical situations.

CANADIAN CT HEAD RULE [23-25]

Summary Statement:
The Canadian CT Head Rule (CCHR) is a widely validated CDR for use in the emergency department for patients with minor head injury to identify clinically important brain injuries on CT scan that may require neurosurgical intervention. It has 5 high-risk clinical factors that, if any are present, indicate a substantial risk that the patient will require neurosurgical intervention. An additional 2 medium-risk factors can be used to determine if the patient has a risk of clinically important lesions on CT that would not require neurosurgical intervention.

<u>Development and validation:</u>
The rule was developed using data from 3,121 patients across 10 Canadian communities and teaching institutions. The high-risk factors were 100% sensitive (95% confidence interval [CI] 92%-100%) for predicting need for neurosurgical intervention and 68.7% specific (95% CI 67%-70%). The medium-risk factors had a sensitivity of 98.4% (95% CI 96%–99%) and specificity of 49·6% (95% CI 48%-51%) for predicting clinically important brain injury demonstrated on a CT scan.

The CCHR was externally validated in 9 tertiary hospitals in Canada using data from a sample of 2707 adults with mild head injury (defined as blunt head trauma resulting in witnessed loss of consciousness, disorientation, or definite amnesia and a GCS score of 13 to 15). The CCHR had a sensitivity of 100% (95% CI 91%-100%) for 41 patients requiring neurosurgical intervention and a specificity of 65.6% (95% CI 64%-67%). For clinically important brain injury the sensitivity was 100% (95% CI 98%-100%) and the specificity was 41.1% (95% CI 39%-43%). A number of other validation studies of the CCHR have occurred since (see evidence table – Appendix One).

The Canadian CT Head Rule and NOC were compared in a subgroup of 1822 adults with minor head injury and a GCS score of 15. Both clinical decision rules had a sensitivity of 100% (95% CI 96%-100%) for 'clinically important brain injury' but the respective specificities were 50.6% (CCHR) vs. 12.7% (NOC). A similar study was carried out in Tunisia where data from 1,582 patients from 7 hospitals were used to compare the performance of the CCHR and NOC. The CCHR had higher sensitivity and specificity than the NOC. Sensitivity and specificity for need for neurosurgical intervention were 100% (95% CI 90% - 100%) and 60% (95% CI 44% - 76%) for the CCHR and 82% (95% CI 69% - 95%) and 26% (95% CI 24% - 28%) for the NOC. Sensitivity and specificity for clinically significant head CT findings were 95% (95% CI 92% - 98%) and 65% (95% CI 62% - 68%) for the Canadian CT Head Rule and 86% (95% CI 81% - 91%) and 28% (95% CI 26% - 30%) for the New Orleans Criteria.

In a separate study[23], the predictive performance of the CCHR was compared to the NOC and the NEXUS II rules. Data was collected from 7,131 patients from 5 tertiary academic EDs in Korea. The sensitivity and specificity for clinically important brain injury were as follows: CCHR, 112 of 144 (79.2%, 95% CI 70.8% - 86.0%) and 228 of 552 (41.3%, 95% CI 37.3% - 45.5%); NOC, 91 of 99 (91.9%, 95% CI 84.7% - 96.5%) and 125 of 558 (22.4%, 95% CI 19.0% - 26.1%); and NEXUS-II, 511 of 576 (88.7%, 95% CI 85.8% - 91.2%) and 1,104 of 2,375 (46.5%, 95% CI 44.5% - 48.5%). The sensitivity and specificity for neurosurgical intervention were as follows: CCHR, 100% (95% CI 59.0% - 100.0%) and 38.3% (95% CI 34.5% - 41.9%); NOC, 100% (95% CI 54.1% - 100.0%) and 20.4% (95% CI 17.4% - 23.7%); and NEXUS-II, 95.1% (95% CI 90.1% - 98.0%) and 41.4% (95% CI 39.5% - 43.2%). For clinically important brain injury, the three CT decision rules had much lower sensitivities in this population than the original published studies, while the specificities were comparable to those studies. The sensitivities for neurosurgical intervention, however, were comparable to the original studies.

Steps for applying the CCHR

There are three broad steps involved in applying the Canadian CT Head Rule to determine the need for head CT imaging.

1. Does my patient have **all** inclusion criteria that would allow the rule to be applied to them?

   Inclusion criteria for The Canadian CT Head Rule:

   i. blunt trauma to the head resulting in **witnessed loss of consciousness, definite amnesia, or witnessed disorientation** (no matter how brief, as reported by the patient or witness);
   ii. **initial** emergency department **GCS score of 13, 14 or 15** as determined by the treating physician;
   iii. injury within the **previous 24 hours.**

2. Does my patient have **any** exclusion criterion that would prevent the rule being applied to them?

   If you answer 'Yes' to all of the inclusion criteria, then ask yourself does your patient have **any** exclusion criterion that would prevent the rule being applied to them?

   Exclusion criteria for the Canadian CT Head Rule:

   i. Age less than 16 years old (other clinical decision rules such as PECARN are available for use in people under 16 – see Paediatric Head Trauma Module for more details).
   ii. **Emergency department GCS score less than 13.**
   iii. Minimal head injury (i.e. no loss of consciousness, amnesia, or disorientation).
   iv. No clear history of trauma as the primary event.
   v. Head injury occurred more than 24 hours previously.
   vi. **An obvious penetrating skull injury or obvious depressed skull fracture.**
   vii. **Focal neurological deficit.**
   viii. **Unstable vital signs associated with major trauma.**
   ix. **Seizure prior to assessment in ED.**
   x. **Bleeding disorder or use of oral anticoagulants.**
   xi. Returned for assessment of the same injury.
   xii. Pregnant.

   For patients with any of the **exclusion criteria in bold**, CT should be performed due to the higher likelihood of clinically important intracranial injury.

3. If no exclusion criteria then use the Canadian CT Head Rule to determine the need for CT

   For patients with any of the exclusion criteria in **bold** outlined in Step 2, CT should be performed due to the higher likelihood of clinically important intracranial injury.

   For patients with one or more of the other exclusion criteria, the need for CT is based on clinical judgment:

   - Children under 16 should have a paediatric specific CDR applied (See Paediatric Head Trauma Module).
   - Pregnant women who need CT based on history, injury mechanism, and clinical findings should have lead shielding applied to the chest and abdominal area during the CT. The foetal dose from a single head CT scan performed on the mother is extremely low and should not prevent clinically needed maternal head CT.

Algorithm

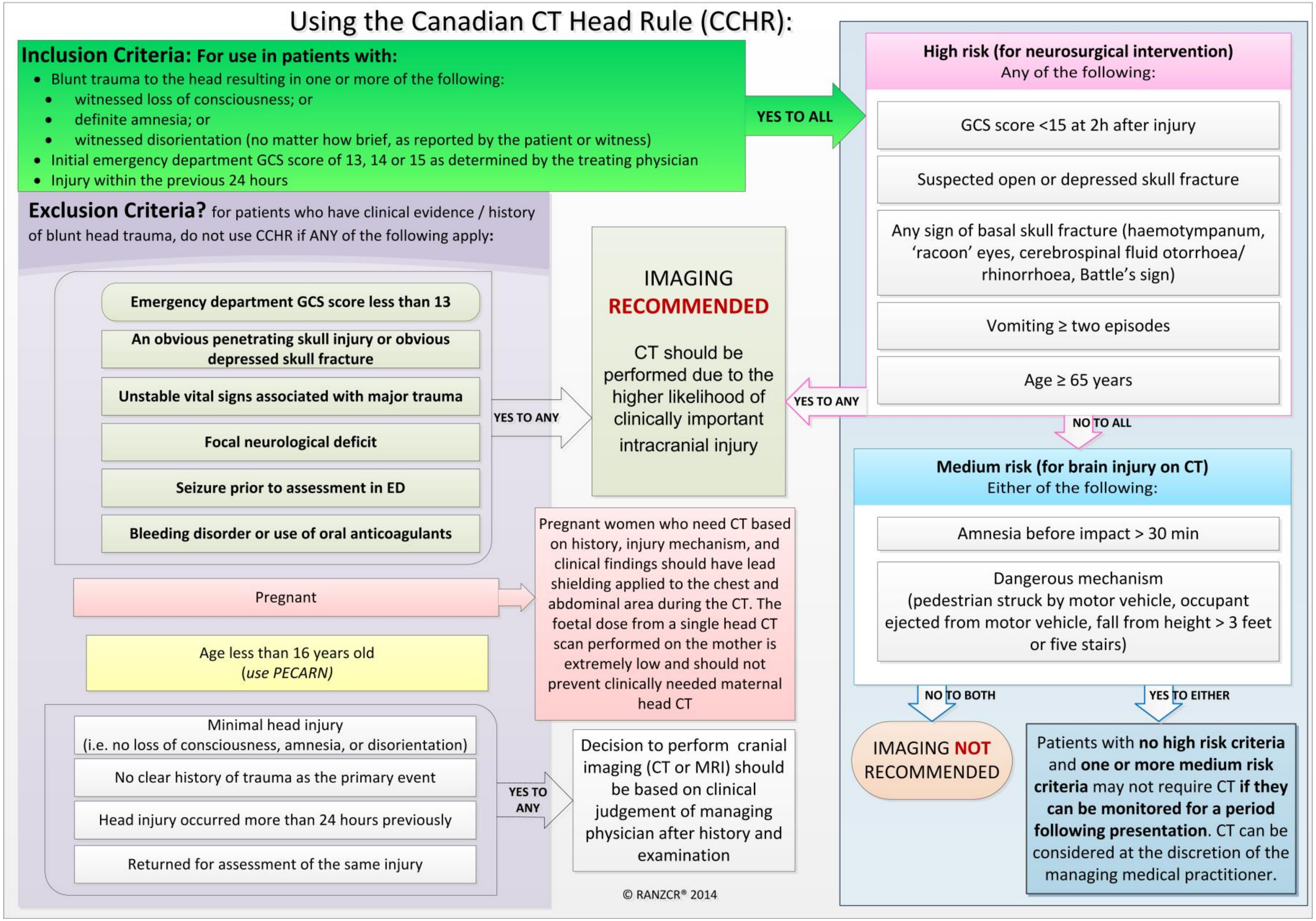

FIGURE 2 - STEPS INVOLVED IN APPLYING THE CANADIAN CT HEAD RULE TO DETERMINE THE NEED FOR HEAD CT

Question 3.

Which of the following are true based on the Canadian CT Head Rule? Select all possible answers.

3A. Normal GCS and absence of amnesia in an adult with acute head injury are accurate predictors of the lack of clinically important head injury.

3B. A patient who is seen 45 minutes after a head injury who has a GCS of 15 may need a CT depending on what else is found upon taking a history and examining him.

3C. Severe headache combined with one episode of vomiting are predictive of the presence of significant intracranial injury.

3D. A palpable skull fracture is an indication for CT scanning after an acute head injury.

3E. All of the above.

CORRECT ANSWER:

Which of the following are true?

3B. A patient who is seen 45 minutes after a head injury who has a GCS of 15 may need a CT depending on what else is found upon taking a history and examining him.

3D. A palpable skull fracture is an indication for CT scanning after an acute head injury.

QUESTION 4.

The Canadian Head CT Rule cannot be applied to which of the following? Select all possible answers.

4A. Individuals over 70.

4B. Individuals under 18.

4C. People taking dabigatran or coumadin derivative medications.

4D. People with clinical evidence of a base of skull fracture.

4E. A 24 year old man with headache, GCS 15 after blunt head trauma on a football ground but no amnesia, disorientation or witnessed loss of consciousness.

CORRECT ANSWER:

The Canadian Head CT rules cannot be applied to:

4C. People taking dabigatran or coumadin derivative medications.

4E. A 24 year old man with headache, GCS 15 after blunt head trauma on a football ground but no amnesia, disorientation or witnessed loss of consciousness.

NEW ORLEANS CRITERIA (NOC)

Summary Statement:

The New Orleans Criteria (NOC)[20] are a set of 7 clinical criteria that can be used to identify patients with minor head injury who need to undergo CT. If any single criterion is present, the rule states that a CT head should be performed due to increased risk of intracranial injury.

DEVELOPMENT AND VALIDATION:
The criteria were developed in 2 phases at a large, inner-city, level 1 trauma centre. The initial derivation study had a relatively small sample size (502 consecutive patients). The clinical findings from the derivation study were prospectively validated in a separate group of 909 consecutive patients. It is unclear from the original report how many children were in the study group and therefore there should be significant reservations about the applicability of the results of this study to the paediatric age group without the NOC being validated in another group of children. The criteria were found to have a sensitivity of 100% (95% CI 95%-100%) for predicting a positive scan and had a specificity of 25% (95% CI 22% - 28%).

The NOC have been externally validated by Stiell et al in 2005[23] in a prospective cohort study in 9 tertiary hospitals, and compared, in the same validation study, to the Canadian CT Head Rule (CCHR). 2,707 patients were enrolled in the study. This validation study found that both clinical decision rules had a sensitivity of 100% (95% CI 96%-100%) for 'clinically important brain injury' but the respective specificities were 50.6% (CCHR) vs. 12.7% (NOC). This validation study was restricted to people aged 16 to 99 years, unlike the original New Orleans Criteria derivation study that enrolled children as young as 3.

It demonstrates that the NOC should result in no missed injuries of significance in adolescents and adults, but that the poor specificity of the NOC relative to the CCHR has the potential to result in in unnecessary imaging. **Therefore, when a patient is eligible for use of either the CCHR or the NOC, the CCHR should be used because of its higher specificity.**

Inclusion criteria:

- Patients with minor head injury (loss of consciousness or amnesia, normal findings on neurological examination and a GCS of 15).
- At least 3 years old.
- Presented within 24 hours after injury.

Exclusion criteria:

- Patients who had concurrent injuries that precluded the use of CT.
- Patients who reported no loss of consciousness or amnesia for the traumatic event.

Algorithm:

New Orleans Criteria
Computed tomography is required for patients with minor head injury with any 1 of the following findings. The criteria apply only to patients who also have a Glasgow Coma Scale score of 15. 1. Headache 2. Vomiting 3. Older than 60 years 4. Drug and alcohol intoxication 5. Persistent anterograde amnesia (deficits in short-term memory) 6. Visible trauma above the clavicle 7. Seizure

TABLE 3 – THE NEW ORLEANS CRITERIA

QUESTION 5.

Which criteria predict the need for CT for both the Canadian CT Head Rule and the New Orleans Criteria? Select all possible answers.

5A. Headache
5B. Amnesia for events that occurred MORE THAN 30 minutes prior to the head injury event
5C. Any vomiting
5D. A seizure
5E. Age > 65 years

CORRECT ANSWER:

Which criteria predict the need for CT for both the Canadian CT Head Rule and the New Orleans Criteria:

5E. Age > 65 years

FEEDBACK: if the patient is over 65 years of age use of either the CCHR or NOC would predict the need for CT.

NATIONAL EMERGENCY X-RADIOGRAPHY UTILIZATION STUDY (NEXUS) II

Summary statement:

The National Emergency X-Radiography Utilization Study (NEXUS II)[21, 22] has 8 clinical criteria that can be used to identify those patients with minor head injury with potential intracranial injuries. If any single criterion is present, a CT is required.

DEVELOPMENT AND VALIDATION:
The criteria were developed using data from 13,728 patients across 21 centres (917 of which had clinically important intracranial injuries, and 330 of which were classified as having a minor head injury). The clinical criteria have a sensitivity of 98.3% (95% CI 97.2%-99%) for clinically important intracranial injuries and specificity of 13.7% (95% CI 13.1%-14.3%).

A paediatric cohort of 1666 children, including infants less than one year old, was enrolled in NEXUS II[26]. 138 (8.3%) children had clinically important ICI. The decision instrument correctly identified 136 of the 138 cases and classified 230 as low risk. A total of 309 children were younger than 3 years, among whom 25 had ICI. The decision instrument identified all 25 cases of clinically important ICI in this subgroup.

The specificity of this CDR appears to be considerably less than for CCHR meaning that more patients with no or clinically insignificant head injury would be exposed to imaging if NEXUS II were used.

At the time this educational module was being prepared in early 2013, this CDR required external validation.

Inclusion criteria:

- Patients with blunt trauma with minor head injury (GCS 15).

Exclusion criteria:

- Patients without blunt trauma (including penetrating head injuries).
- Patients undergoing CT for other reasons.

Algorithm:

NEXUS II
If any of the following are present, CT **is** required. If none are present, CT is **not** required: • evidence of significant skull fracture • scalp haematoma • neurologic deficit • altered level of alertness • abnormal behaviour • coagulopathy • persistent vomiting • age 65 years or more

TABLE 4 – 8 CLINICAL CRITERIA FOR THE NEXUS II RULE

3. What else do you need to think about, other than pre-test probability of a condition, when you are considering performing diagnostic imaging in a patient with blunt head trauma?

Urgency:

Patients with more severe alteration in conscious state, focal neurological signs or clinical evidence of skull vault or skull base fracture require urgent CT scanning. Patients who meet criteria for mild head injury and who have risk factors for abnormal CT, but no risk factors for increased likelihood of neurosurgical intervention, may be managed with a period of clinical observation. The decision to perform CT can be based on clinical judgement about the evolution of signs and symptoms during an observation period.

Radiation dose:

The radiation dose from a single head CT scan performed on an adult is between 1 and 2 millisieverts (mSv).

- **MRI –** In a patient with normal head CT and persistent focal neurology MRI can be used to demonstrate pathology not shown on a CT such as acute stroke, brainstem abnormality or diffuse axonal injury.
- **CT angiography** – is used to diagnose blunt injury to the vertebral or carotid arteries in the following situations:
  - Evidence of acute stroke on CT scan (this may not be evident for hours or days after the acute injury) or development of focal neurological signs that may indicate acute stroke due to carotid or vertebral artery injury or dissection.
  - Fractures involving the foramen transversarium (this is where the vertebral artery passes through each vertebra).
- **Iodinated contrast –** Administration of iodinated contrast is almost never indicated for CT performed in conjunction with acute head trauma unless you are performing CT angiography. Therefore, renal function assessment prior to CT will generally not be required.
- **Anticoagulation –** In a patient receiving anticoagulation with blunt head trauma, the Canadian CT Head Rule cannot be used. There is clinical equipoise regarding whether CT scanning should be mandatory in such patients if they are neurologically intact and have a normal GCS[27].
- However, a Best Bets review conducted in 2010[28] found a number of case series showing a small, unquantifiable increased risk of DELAYED intracranial haemorrhage in these patients, even when the initial CT is normal. Therefore, regardless of whether an initial CT is performed, this review concluded:
  - INR should be checked and corrected if not in the therapeutic range.
  - Therapeutic INR levels should not necessarily be reassuring regarding risk of delayed haemorrhage.
  - Observation for a period after the head injury is prudent regardless of the normality of an initial CT.
  - Whether observation is carried out at home or in hospital will depend upon the patient's circumstances and support.
  - There is no high level evidence to indicate the appropriate duration for observation but 24 hours has been suggested in the Best Bets review.

Further studies are needed to quantify the risk of delayed intracranial haemorrhage in neurologically intact anti-coagulated patients with blunt head trauma.

MODALITY TABLE:

MODALITY	STRENGTHS	WEAKNESSES	COMMENTS
CT **Link:** *http://www.insideradiology.com.au/pages/view.php?T_id=61*	• Readily available. • Fast to perform (1 minute or less once the patient is positioned and immobilised on the CT table). • Highly accurate for intracranial injuries requiring surgical treatment. • Sensitive for calvarial and skull base fractures. • Can be performed easily in patients who are intubated and being monitored due to severe injuries.	• Ionising radiation. • Insensitive to: ○ vascular injuries (vertebral and carotid dissection, caroticocavernous fistula, traumatic intracranial pseudoaneurysms) unless CT angiography (CTA)is performed; ○ diffuse axonal injury; ○ mild parenchymal contusion.	
MRI **Link:** *http://www.insideradiology.com.au/pages/view.php?T_id=53*	• Uses magnetic field and radiofrequency pulses to produce an image. • No ionising radiation. • Sensitive to brain parenchymal and vascular injury.	• Takes longer than CT (20 minutes). • Not readily available to every emergency department . • Harder to monitor unstable patients in the MRI environment. • Confused patients may need general anaesthesia to avoid motion degradation of the images due to long acquisition time. • Does not demonstrate most calvarial/skull base fractures. • Ferromagnetic foreign bodies (e.g. bullets, metal fragments) in the patient may move during scanning and thus represent a contraindication. • Pacemakers, some types of implants are contraindications to MRI as they malfunction and/or move in the MR environment.	Modality of choice for subacute head injury. Used to investigate persistent cognitive, neurological, behavioural abnormalities unexplained by CT and to provide prognostic information.
Skull radiographs	• Useful for demonstrating skull vault fracture.	• Not routinely used to image adults with head injury as it does not allow evaluation of intracranial injury.	

TABLE 5: IMAGING MODALITIES FOR BLUNT TRAUMA TO THE HEAD

Question 6.

A 43 year old man is riding on a bicycle path on his way to work at 0745. A dog runs across the path at this time, causing him to swerve into a signpost, resulting in him falling off his bike and hitting his head on the pavement of the bicycle path. The dog's owner comes to his aid. He is unresponsive for "about a minute" according to the dog walker, during which time she phones an ambulance. In the ambulance, he vomits once. In the emergency department at 0915 his GCS is 15, he has a headache and he has no neurological findings. He remembers getting on his bike at home, less than 500m from the location of the accident, and then remembers nothing until waking up on the ground next to his bike. While he was being evaluated his wife arrived and she is very concerned that he has a brain injury and is asking you if he is to be admitted to hospital. You noticed his right mid clavicle looked swollen and a radiograph (x-ray) has shown a fracture. The man takes antihypertensive medication but is otherwise well and not on other medications.

Which of the following are true? Select all possible answers.

6A. His persistent headache and amnesia for the 5 minute trip between his home and the accident increase the likelihood of significant intracranial injury and I would do a CT scan based on the Canadian CT Head Rule.

6B. He does not have findings that significantly increase the likelihood that he needs neurosurgical intervention.

6C. His wife should be provided with verbal and written instructions about what to look for and when to bring her husband back to the emergency department after he is discharged.

6D. His fractured clavicle increases the likelihood that he has significant intracranial injury and I would perform a CT of his head.

6E. Falling from a seated position on a road bike represents a dangerous injury mechanism and I would perform a CT of his head.

CORRECT ANSWER:

<u>The following are true:</u>

6B. He does not have findings that significantly increase the likelihood that he needs neurosurgical intervention.

6C. His wife should be provided with verbal and written instructions about what to look for and when to bring her husband back to the emergency department after he is discharged.

Question 7.

A 17 year old plays football for his school team on a Saturday morning. He collides head on with one of the other players and is knocked out. He is dazed and not responding to people around him when he is carried off the ground on a stretcher. He regains consciousness after a couple minutes and then vomits. He says he has a bad headache and is groaning. His mother travels with him in the ambulance to the local emergency department. When you see him, an hour after the accident, his GCS is 14. He has no focal neurological signs and nothing abnormal to find on examination. His father arrives and is surprised that his son does not remember the accident. He is demanding an immediate CT scan because he is worried there is something seriously wrong and he tells you he is a lawyer.

What would you do in the situation described? Select all possible answers.

7A. Explain that your assessment of his son is that he most likely has a mild head injury.

7B. Explain that CT can potentially be avoided if his conscious state returns to normal over the next hour and you would advise a period of in hospital observation for this reason.

7C. Explain that if this expected resolution in his current confusion does not happen, a CT would be a good idea.

7D. Perform an immediate CT as it is likely that he will need one anyway.

7E. Consider the possibility that he may also have cervical spine injury based on injury mechanism.

CORRECT ANSWER:

You do the following:

7A. Explain that your assessment of his son is that he most likely has a mild head injury.

7B. Explain that CT can potentially be avoided if his conscious state returns to normal over the next hour and you would advise a period of in hospital observation for this reason.

7C. Explain that if this expected resolution in his current confusion does not happen, a CT would be a good idea.

7E. Consider the possibility that he may also have cervical spine injury based on injury mechanism.

Question 8.

A 21 year old engineering student is running to lectures and slips on some wet stairs. He falls down the stairs and hits his head. A few minutes later, a passer-by finds him lying at the bottom of the flight of 5 stairs. He is dazed and does not know what happened. He is taken to the university medical centre for assessment and you see him within half an hour of the fall. He is complaining of a bad headache and on examination has diplopia when he looks to the left but not the right. His GCS is 14. You have CT facilities at the university medical centre but no neurosurgical service.

Which of the following actions would you take? Select all possible answers.

8A. Observe him until 2 hours has elapsed since his head injury to see if his GCS returns to normal.

8B. Organise urgent transfer to the nearest emergency department with a neurosurgical service.

8C. Perform an urgent CT scan of his head and cervical spine prior to transfer to the nearest emergency department with a neurosurgical service.

8D. None of the above.

CORRECT ANSWER:

<u>What do you do?</u>

8B. Organise urgent transfer to the nearest emergency department with a neurosurgical service.

8C. Perform an urgent CT scan of his head and cervical spine prior to transfer to the nearest emergency department with a neurosurgical service.

Question 9.

A 78 year old man gets up in the middle of the night to go to the toilet. In the dark, he slips and falls over the dog who is asleep at the foot of the bed. He hits his head on the windowsill on the way to the floor and cannot get up. His startled 72 year old wife gets out of bed and sees him lying on the floor with a cut on his right forehead that is actively bleeding. He seems a bit dazed. She calls an ambulance. On arrival in the ED 45 minutes later, he has a GCS of 15, a large haematoma on his right forehead and a small cut overlying this. His current medications are clopidogrel (he had a carotid endarterectomy 3 years ago) and a statin to treat hypercholesterolaemia. He is neurologically normal on examination and has no other abnormal physical findings.

Which of the following statements are true? Select all possible answers.

9A. The Canadian CT Head Rule cannot be applied to this patient because he is receiving anticoagulant medication.

9B. The Canadian CT Head Rule cannot be applied to this patient because he is over 65.

9C. A head CT scan should be performed because the patient is both ineligible for use of the Canadian CT Head Rule and theoretically at increased risk of intracranial haemorrhage.

9D. If a CT is performed and shows no evidence of intracranial bleeding the patient is safe to go home with his wife with no further follow up.

9E. If a CT is performed and shows no acute intracranial bleeding there is probably a small (but unquantified) increased risk of intracranial bleeding for the next 24-48 hours.

CORRECT ANSWER:

The following statements are true:

9A. The Canadian CT Head Rule cannot be applied to this patient because he is receiving anticoagulant medication.

9C. A head CT scan should be performed because the patient is both ineligible for use of the Canadian CT Head Rule and theoretically at increased risk of intracranial haemorrhage.

9E**.** If a CT is performed and shows no acute intracranial bleeding there is probably a small (but unquantified) increased risk of intracranial bleeding for the next 24-48 hours.

REFERENCES:

1. Australian Institute of Health and Welfare. Disability in Australia: acquired brain injury. Canberra: AIHW, 2007.
2. Faux S, Sheedy J. A prospective controlled study in the prevalence of posttraumatic headache following mild traumatic brain injury. *Pain Med*. 2008; 9(8): 1001-11.
3. Australian Institute of Health and Welfare. Hospital separations due to injury and poisoning, Australia 2009-10. Canberra: AIHW, 2012.
4. Haydel M. Management of mild traumatic brain injury in the emergency department. *Emerg Med Pract*. 2012; 14(9): 1-24.
5. Centers for Disease Control and Prevention. MTBI report to Congress on mild traumatic brain injury in the United States: Steps to prevent a serious public health problem. Atlanta: National Center for Injury Prevention and Control, 2003.
6. Vanderploeg RD, Curtiss G, Luis CA, Salazar AM. Long-term morbidities following self-reported mild traumatic brain injury. *J Clin Exp Neuropsychol*. 2007; 29(6): 585-98.
7. Rosenfeld JV, Maas AI, Bragge P, Morganti-Kossmann MC, Manley GT, Gruen RL. Early management of severe traumatic brain injury. *Lancet*. 2012; 380(9847): 1088-98.
8. Ponsford J. Understanding and managing traumatic brain injury. InPsych: The Bulletin of the Australian Psychological Society Ltd [Internet]. April 2012 14th June 2012. Available from: http://www.psychology.org.au/publications/inpsych/2012/#s5.
9. Pandor A, Goodacre S, Harnan S, Holmes M, Pickering A, Fitzgerald P, et al. Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. *Health Technol Assess*. 2011; 15(27): 1-202.
10. Carroll LJ, Cassidy JD, Peloso PM, Borg J, von Holst H, Holm L, et al. Prognosis for mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *J Rehabil Med*. 2004; (43 Suppl): 84-105.
11. Finkelstein E, Corso P, Miller T, Associates. The Incidence and Economic Burden of Injuries in the United States. New York: Oxford University Press; 2006.
12. Reed D. Adult Trauma Clinical Practice Guidelines, Initial Management of Closed Head Injury in Adults. 2nd ed: NSW Institute of Trauma and Injury Management; 2011.
13. Bethel J. Emergency care of children and adults with head injury. *Nurs Stand*. 2012; 26(43): 49-56; quiz 8.
14. Bratton SL, Chestnut RM, Ghajar J, McConnell Hammond FF, Harris OA, Hartl R, et al. Guidelines for the management of severe traumatic brain injury. I. Blood pressure and oxygenation. *J Neurotrauma*. 2007; 24 Suppl 1: S7-13.
15. Haddad SH, Arabi YM. Critical care management of severe traumatic brain injury in adults. *Scand J Trauma Resusc Emerg Med*. 2012; 20: 12.
16. Pearce MS, Salotti JA, Little MP, McHugh K, Lee C, Kim KP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: A retrospective cohort study. *Lancet*. 2012; 380(9840): 499-505.
17. Mathews JD, Forsythe AV, Brady Z, Butler MW, Goergen SK, Byrnes GB, et al. Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians. *BMJ*. 2013; 346: f2360.
18. Brenner D, Elliston C, Hall E, Berdon W. Estimated risks of radiation-induced fatal cancer from pediatric CT. *AJR Am J Roentgenol*. 2001; 176(2): 289-96.
19. McGinn T, Guyatt G, Wyer P, Naylor C, Stiell I, Richardson W. Users' guides to the medical literature: XXII: how to use articles about clinical decision rules. Evidence-Based Medicine Working Group. *JAMA*. 2000; 284(1): 79-84.
20. Haydel MJ, Preston CA, Mills TJ, Luber S, Blaudeau E, DeBlieux PM. Indications for computed tomography in patients with minor head injury. *N Engl J Med*. 2000; 343(2): 100-5.

21. Mower W, Hoffman J, Herbert M, Wolfson A, Pollack C, Zucker M, et al. Developing a clinical decision instrument to rule out intracranial injuries in patients with minor head trauma: methodology of the NEXUS II investigation. *Ann Emerg Med*. 2002; 40(5): 505-14.

22. Mower WR, Hoffman JR, Herbert M, Wolfson AB, Pollack CV, Jr., Zucker MI. Developing a decision instrument to guide computed tomographic imaging of blunt head injury patients. *J Trauma*. 2005; 59(4): 954-9.

23. Stiell IG, Clement CM, Rowe BH. Comparison of the Canadian CT head rule and the New Orleans criteria in patients with minor head injury. *JAMA*. 2005; 294(12): 1511-8.

24. Stiell IG, Lesiuk H, Wells G, McKnight R, Brison R, Clement C, et al. The Canadian CT Head Rule Study for patients with minor head injury: Rationale, objectives, and methodology for phase I (derivation). *Ann Emerg Med*. 2001; 38(2): 160-9.

25. Stiell IG, Wells GA, Vandemheen K, Clement C, Lesiuk H, Laupacis A, et al. The Canadian CT Head Rule for patients with minor head injury. *Lancet*. 2001; 357(9266): 1391-6.

26. Oman JA, Cooper RJ, Holmes JF, Viccellio P, Nyce A, Ross SE, et al. Performance of a decision rule to predict need for computed tomography among children with blunt head trauma. *Pediatrics*. 2006; 117(2): e238-46.

27. Lindsay E, Burke G. Do anticoagulated patients who sustain a minor head injury require a CT scan to rule out intra-cranial injury? [Online summary of evidence] BestBets.org: BestBets; 2005 [updated 22nd June 2005; cited 2013 27/09/2013]; Available from: http://bestbets.org/bets/bet.php?id=503.

28. Rendell S. Observation is recommended even following a normal CT brain in warfarinised head injuries. [Online summary of evidence] BestBets.org: BestBets; 2010 [updated 11/11/2010; cited 2013 27/09/2013]; Available from: http://bestbets.org/bets/bet.php?id=1949.

29. Stiell IG, Lesiuk H, Wells GA, Coyle D, McKnight RD, Brison R, et al. Canadian CT head rule study for patients with minor head injury: methodology for phase II (validation and economic analysis). *Annals of emergency medicine*. 2001; 38(3): 317-22.

30. Ro Y, Shin S, Holmes J, Song K, Park J, Cho J, et al. Comparison of clinical performance of cranial computed tomography rules in patients with minor head injury: a multicenter prospective study. *Academic emergency medicine*. 2011; 18(6): 597-604.

31. Bouida W, Marghli S, Souissi S, Ksibi H, Methammem M, Haguiga H, et al. Prediction Value of the Canadian CT Head Rule and the New Orleans Criteria for Positive Head CT Scan and Acute Neurosurgical Procedures in Minor Head Trauma: A Multicenter External Validation Study. *Annals of emergency medicine*. 2012; 61(5): 521-7.

APPENDIX ONE - EVIDENCE TABLE

Author and date	Name of CDR	Derivation or validation	Inclusion	Exclusion	Sensitivity (95%ci)	Specificity (95% ci)	LR- (95%CI)	High performance (y/n)	Hierarchy
Haydel et al, 2000[20]	New Orleans Criteria (NOC)	Both	Patients with minor head injury (Loss of consciousness or amnesia, normal findings on neuro exam, GCS 15) At least 3 years old. Presented within 24 hours after injury.	Patients who declined CT. Patients who had concurrent injuries that precluded the use of CT. Patients who reported no loss of consciousness or amnesia for the traumatic event.	100% (95% CI 95%-100%)	25% (95% CI 22%-28%)	0.2	No (sensitivity is >95% but lR is not <0.1)	level III/IV
Mower et al 2002[21] (and 2005[22] for results)	NEXUS II	Derivation	All patients with blunt trauma with minor head injury (GCS 15)	Patients without blunt trauma (including penetrating head injuries) Patients undergoing CT for other reasons	98.3% (95% CI 97.2% – 99.0%)	13.7% (95% CI 13.1% – 14.3%)	0.12	No (Borderline: LR- is not <0.1)	Level IV
Stiell et al, 2001[24] (Results from Stiell et al, Lancet 2001[25])	The Canadian CT Head Rule Study for Patients with Minor Head Injury	Derivation	Blunt trauma to head resulting in witnessed loss of consciousness, definite amnesia or witnessed deterioration (no matter how brief, as reported by the patient or the witness) Initial Emergency Department GCS 13 or above Injury within the previous 24 hours	< 16 years old GCS < 13 Minimal head injury (i.e. no loss of consciousness, amnesia, or disorientation No clear history of trauma as the primary event Head injury that occurred more than 24 hours previously An obvious penetrating skull injury or obvious depressed skull fracture Focal neurological deficit Unstable vital signs associated with major trauma Seizure prior to assessment in ED Bleeding disorder or used oral anticoagulants Returned for assessment of the same injury Pregnant	Neuro-surgical intervention 100% (95% CI 92% – 100%) Clinically Important Injury 98.4% (95% CI 96%-99%)	Neuro-surgical intervention 68.7% (95% CI 67% – 70%) Clinically Important Injury 49.6% (95% CI 48%-51%)	Neuro-surgical intervention 0 Clinically Important Injury 0.03	Neuro-surgical intervention No Clinically Important Injury Yes	I

Author and date	Name of CDR	Derivation or validation	Inclusion	Exclusion	Sensitivity (95%ci)	Specificity (95% ci)	LR- (95%CI)	High performance (y/n)	Hierarchy
Stiell et al, 2001[29]	Canadian CT Head Rule Study for Patients With Minor Head Injury: Methodology for phase II (Validation and Economic analysis)	Validation	Blunt trauma to head resulting in witnessed loss of consciousness, definite amnesia or witnessed deterioration (no matter how brief, as reported by the patient or the witness) Initial Emergency Department GCS 13 or above Injury within the previous 24 hours	< 16 years old GCS < 13 Minimal head injury (i.e. no loss of consciousness, amnesia, or disorientation No clear history of trauma as the primary event Head injury that occurred more than 24 hours previously An obvious penetrating skull injury or obvious depressed skull fracture Focal neurological deficit Unstable vital signs associated with major trauma A seizure prior to assessment in ED A bleeding disorder or used oral anticoagulants Returned for assessment of the same injury Pregnant	Neuro-surgical intervention 100% (95% CI 92%– 100%)	Neuro-surgical intervention 68.7% (95% CI 67% – 70%)			

Author and date	Name of CDR	Derivation or validation	Inclusion	Exclusion	Sensitivity (95%ci)	Specificity (95% ci)	LR- (95%CI)	High performance (y/n)	Hierarchy
Stiell et al 2005[11]	Canadian CT Head Rule	Validation	Blunt trauma to head resulting in witnessed loss of consciousness, definite amnesia or witnessed deterioration (no matter how brief, as reported by the patient or the witness) Initial Emergency Department GCS>13 or above Injury within the previous 24 hours	< 16 years old GCS < 13 Minimal head injury (i.e. no loss of consciousness, amnesia, or disorientation No clear history of trauma as the primary event Head injury that occurred more than 24 hours previously An obvious penetrating skull injury or obvious depressed skull fracture Focal neurological deficit Unstable vital signs associated with major trauma A seizure prior to assessment in ED A bleeding disorder or used oral anticoagulants Returned for assessment of the same injury Pregnant	GCS 15 Neuro-surgical intervention: 100% (95% CI 63% – 100%) Clinically Important Brain injury: 100% (95% CI 96% – 100%) GCS 13 – 15 Neuro-surgical intervention: 100% (95% CI 91% – 100%) Clinically Important Brain injury: 100% (95% CI 98% – 100%)	GCS 15 Neuro-surgical intervention 76.3% (95% CI 74% – 78%) Clinically Important Brain injury: 50.6% (95% CI 48% – 53%) GCS 13 – 15 Neuro-surgical intervention: 65.6% (95% CI 64% – 67%) Clinically Important Brain injury: 41.1% (95% CI 39% – 43%)	GCS 15 Neuro-surgical intervention: LR =0 Clinically Important Brain injury: LR =0 GCS 13 – 15 Neuro-surgical intervention: LR =0 Clinically Important Brain injury: LR =0	GCS 15 Neuro-surgical intervention *No* Clinically Important Brain injury: *Yes* GCS 13 – 15 Neuro-surgical intervention: *No* Clinically Important Brain injury: *Yes*	

Author and date	Name of CDR	Derivation or validation	Inclusion	Exclusion	Sensitivity (95%ci)	Specificity (95% ci)	LR- (95%CI)	High performance (y/n)	Hierarchy
Ro et al 2011[30]	Canadian CT Head Rule	Validation	Blunt trauma to head resulting in witnessed loss of consciousness, definite amnesia or witnessed deterioration (no matter how brief, as reported by the patient or the witness) Initial Emergency Department GCS 13 or above Injury within the previous 24 hours	< 16 years old GCS < 13 Had minimal head injury (i.e. no loss of consciousness, amnesia, or disorientation Had no clear history of trauma as the primary event Head injury that occurred more than 24 hours previously Had an obvious penetrating skull injury or obvious depressed skull fracture Had focal neurological deficit Unstable vital signs associated with major trauma Had a seizure prior to assessment in ED Had a bleeding disorder or used oral anticoagulants Had returned for assessment of the same injury Pregnant	Clinically Important Brain Injury 79.2% (95% CI 70.8% – 86.0%) Neuro-surgical intervention 100% (95% CI 59% – 100%)	Clinically Important Brain Injury 41.3% (95% CI 37.3% – 45.5%) Neuro-surgical intervention 38.3% (95% CI 34.5% – 41.9%)	Clinically Important Brain Injury LR =0.50 Neuro-surgical intervention LR = 0	Clinically Important Brain Injury No Neuro-surgical intervention No	
Bouida et al 2012[31]	Canadian CT Head Rule	Validation	Blunt trauma to head resulting in witnessed loss of consciousness, definite amnesia or witnessed deterioration (no matter how brief, as reported by the patient or the witness) Initial Emergency Department GCS 13 or above Injury within the previous 24 hours	< 16 years old GCS < 13 Minimal head injury (i.e. no loss of consciousness, amnesia, or disorientation No clear history of trauma as the primary event Head injury that occurred more than 24 hours previously An obvious penetrating skull injury or obvious depressed skull fracture Focal neurological deficit A seizure prior to assessment in ED A bleeding disorder or used oral anticoagulants Returned for assessment of the same injury Pregnant	Clinically Important Head injury 95% (95% CI 92% – 98%) Neuro-surgical intervention 100% (95% CI 90% – 100%)	Clinically Important Head Injury 65% (95% CI 62% – 68%) Neuro-surgical intervention 60% (95% CI 44% – 76%)	Clinically Important Brain Injury LR = 0.08 Neuro-surgical intervention LR = 0	Clinically Important Brain injury *No* Neuro-surgical intervention *No*	

*High performance (Y/N) for the derivation study defined as:

- Sens > 0.95 AND
- Lower limit of 95%CI for sensitivity >0.95 AND
- LR-<0.1 AND
- Upper limit of LR-95% CI < 0.1
- Likelihood ratio for negative test result $= \frac{\text{proportion of patients WITH disease who have a negative test result (1 – SENSITIVITY)}}{\text{proportion of patients WITHOUT disease who have a negative test result (SPECIFICITY)}} = \frac{\text{(1 – SENSITIVITY)}}{\text{(SPECIFICITY)}}$

**Hierarchy (see reference I. below)

Level I: can be used in a variety of clinical settings and includes at least one validation study (external) and at least one impact analysis showing favourable change in clinician behaviour when the CDR is used/implemented

Level II: can be used in various setting with confidence about accuracy (1 prospective validation in heterogeneous population or several smaller ones)

Level III: use with caution in narrowly defined group of patients (validated in one narrow prospective sample)

Level IV: CDRs requiring more evaluation before they are implemented (no validation or only validated with statistical techniques or retrospective databases, or split samples)

APPRAISAL TABLE REFERENCES:

I. McGinn T, Guyatt G, Wyer P, Naylor C, Stiell I, Richardson W. Users' guides to the medical literature: XXII: how to use articles about clinical decision rules. Evidence-Based Medicine Working Group. *JAMA*. 2000; 284(1): 79-84.

II. Pickering A, Harnan S, Fitzgerald P, Pandor A, Goodacre S. Clinical decision rules for children with minor head injury: A systematic review. *Arch Dis Child*. 2011; 96(5): 414-21.

Appendix Two – The Canadian CT Head Rule